BTeV Trigger and DAQ Innovations

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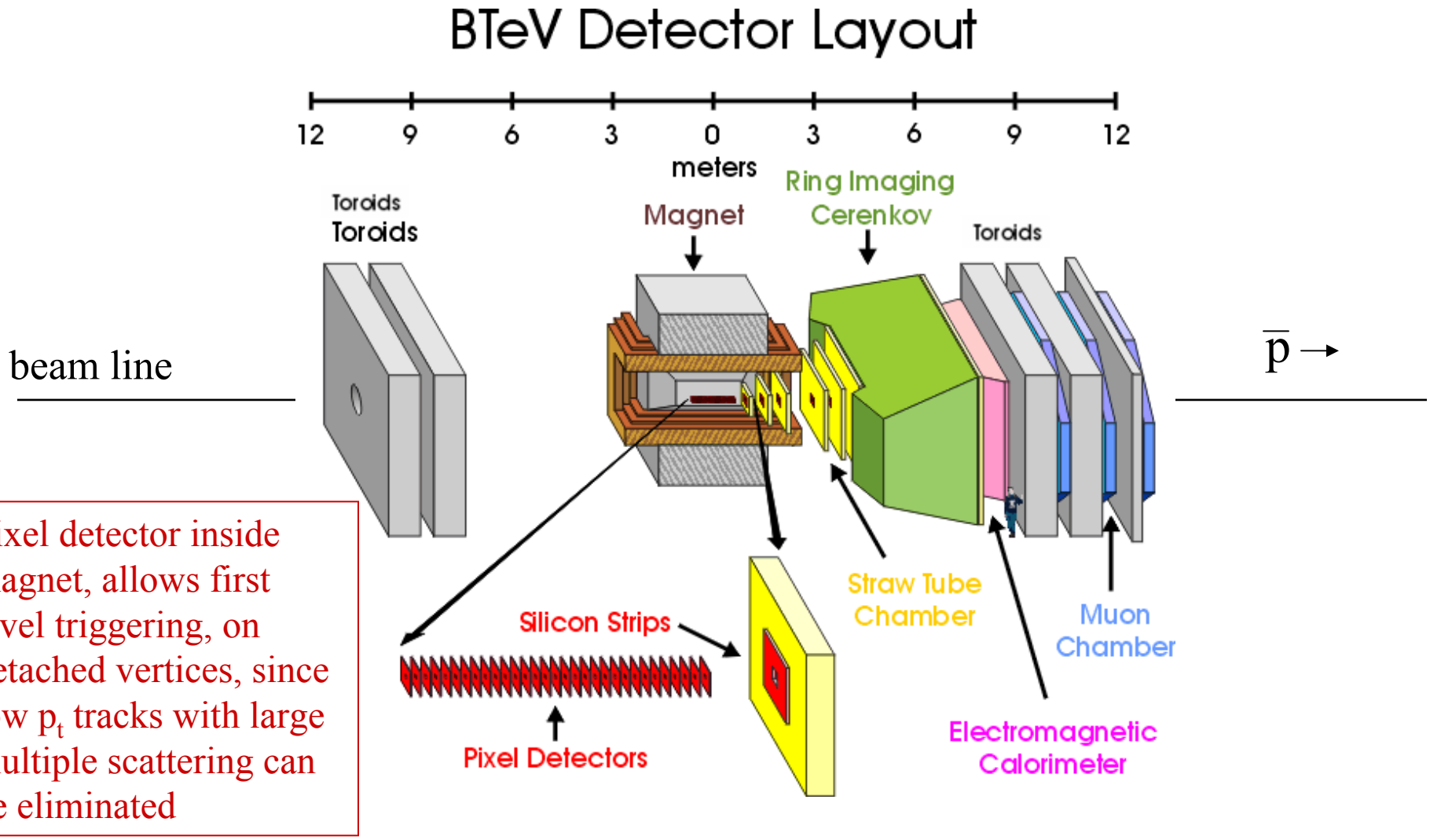
The BTeV Detector



Pixel detector inside magnet, allows first level triggering, on detached vertices, since low p_t tracks with large multiple scattering can be eliminated

BTeV Background

- B-physics experiment proposed at Fermilab
  - www-btev.fnal.gov
  - 170 physicists from 30 universities/institutions worldwide (and growing)
  - $193M construction project ($141M base + $52M contingency)
    - DAQ and Trigger were 2 separate subprojects accounting for 17% of the project cost combined.
- Timeline
  - In R&D since 1996 (!)
  - Construction to have begun in FY2005
  - Two stage delivery (to match funding profile) with ~50% capacity in FY09 and the remaining in FY10.
  - Successfully passed CD2/CD3a (ie, limited construction funds available) review in December 2004.
  - Cancelled abruptly in February, 2005 by the Department of Energy

Online Requirements

- The challenge for the BTeV trigger and data acquisition system is to reconstruct particle tracks and interaction vertices for **EVERY** interaction that occurs in the BTeV detector, and to select interactions with *B* decays.
- The trigger performs this task using 3 levels, referred to as Levels 1, 2, and 3:
  "L1" – looks at every interaction and rejects at least 98% of min. bias background
  "L2" – uses L1 computed results & performs more refined analyses for data selection
  "L3" – rejects additional background and performs data-quality monitoring

Reject > 99.9% of background. Keep > 50% of *B* events.

- The data acquisition system saves all of the data in memory for as long as necessary to analyze each interaction, and moves data to L2/3 processing units and archival data storage for selected interactions.
  - Complex algorithms => long latencies (1 msec for L1)
- The key ingredients that make it possible to meet this challenge:
  - BTeV pixel detector with its exceptional pattern recognition capabilities
  - Rapid development in technology – FPGAs, processors, networking
- I/O rates
  - 21M channels, dominated by Pixel detector
  - Input rate 2.5MHz x 200KBytes/event = 500 Gbytes/sec.
  - Output rate = 2.5 KHz x 80 Kbytes/event = 200 Kbytes/sec
    - 1 PByte/year

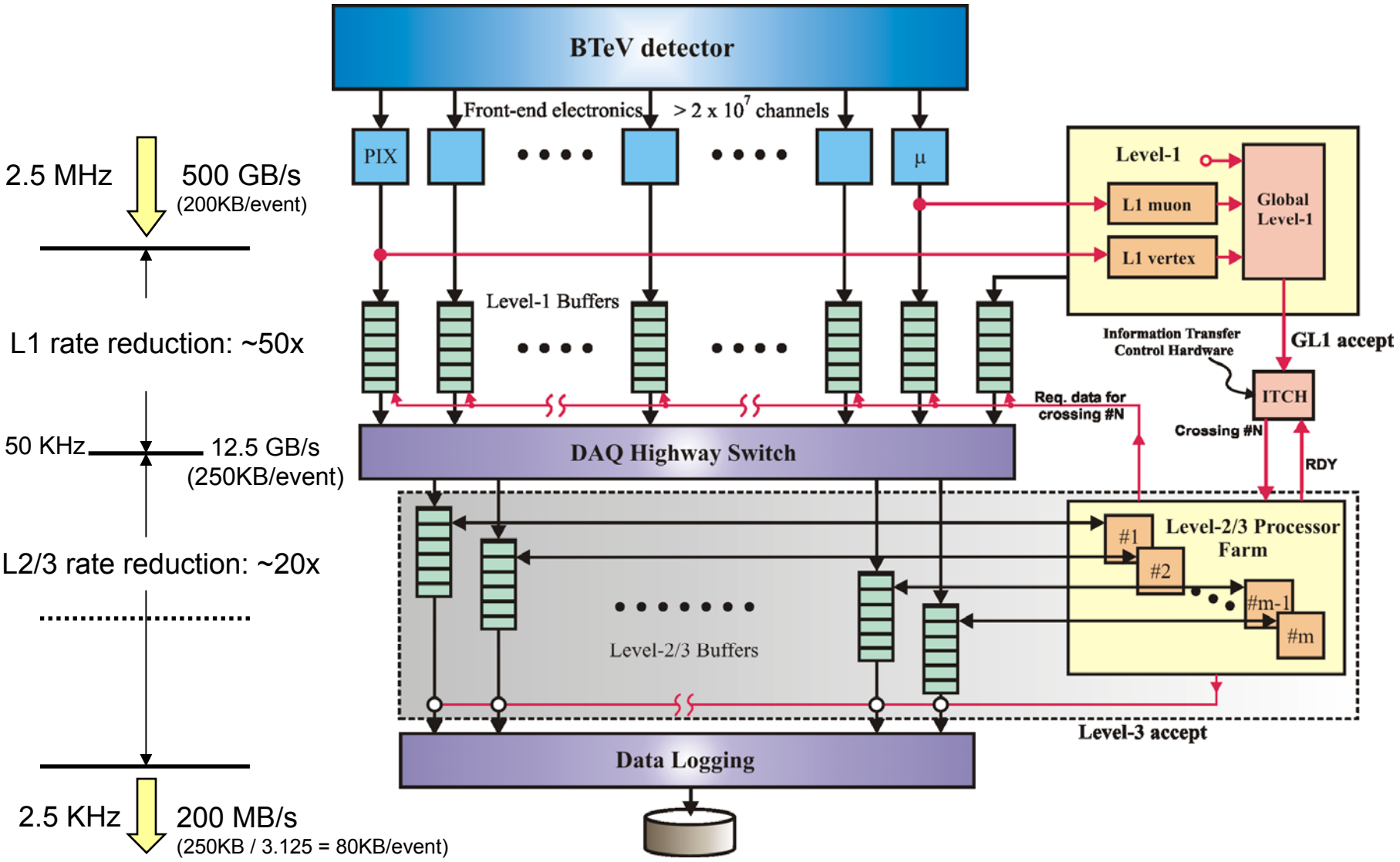
How to do this Affordably?

- Fast data links between detector and online system
- Sophisticated L1 track findingTrigger
- Commodity hardware wherever possible.
- Use inexpensive DRAM-type buffer memory off detector
- Only point-point serial links (copper and optical)
- Subdivide system into 8 parallel highways

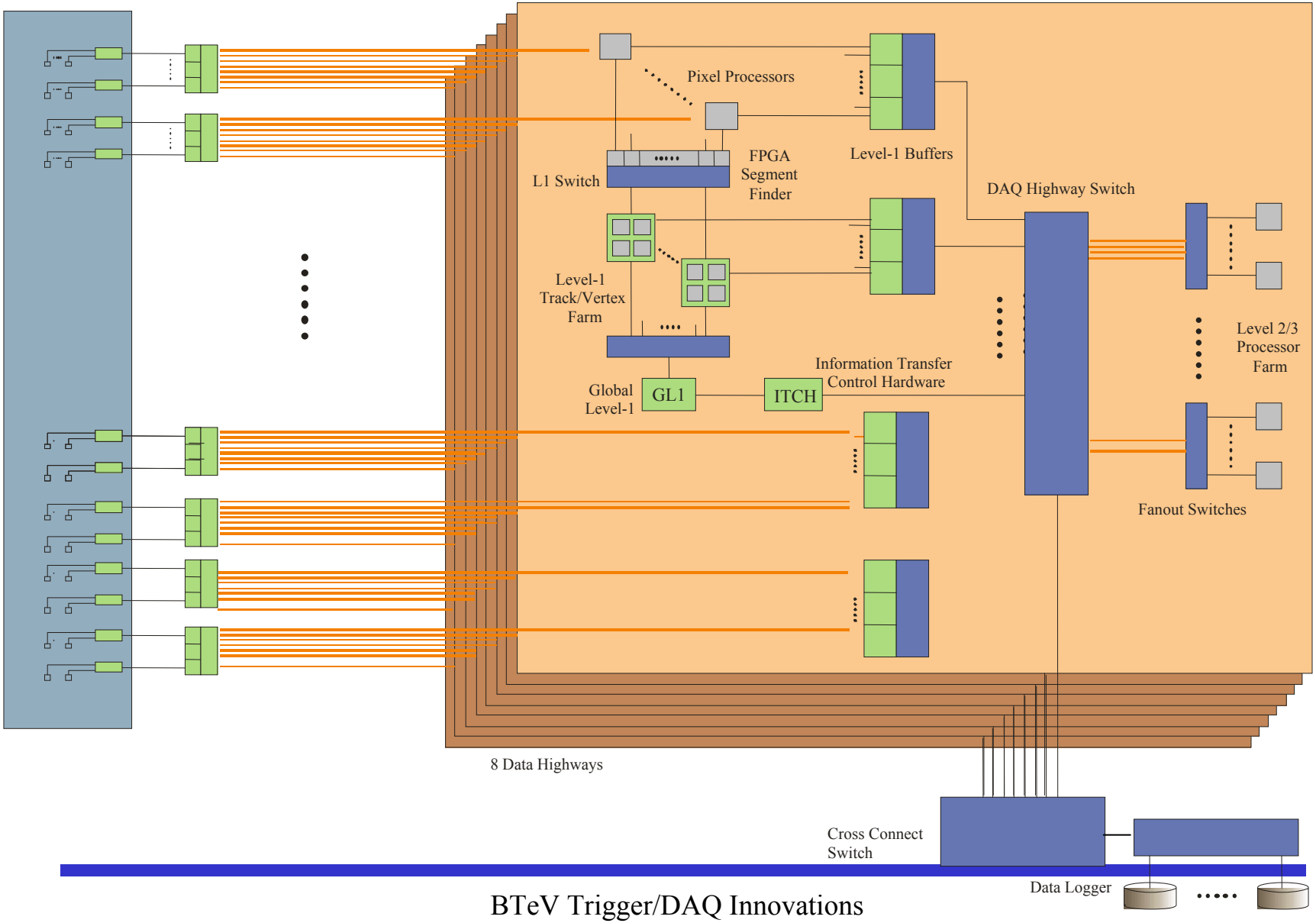
Online Architecture Credible

- Detailed work break down structure for complete experiment.
  - Fully burdened resource loaded schedule
  - ~6000 activities for trigger/DAQ.
  - Risk analysis understood and mitigation strategies planned.
  - Included both cost and schedule contingency. Online system completed at least 9 months before it was needed.
- Heavily reviewed.
  - Went before P5 subpanel (twice!)
  - External CD0, CD1, and CD2/3a, each preceeded by an internal director's review.
  - BTeV passed the final review – CD2/3a with notably favorable comments from the review committee.
- Prototyping
  - L1 Trigger prototyped
  - Prepilot being assembled

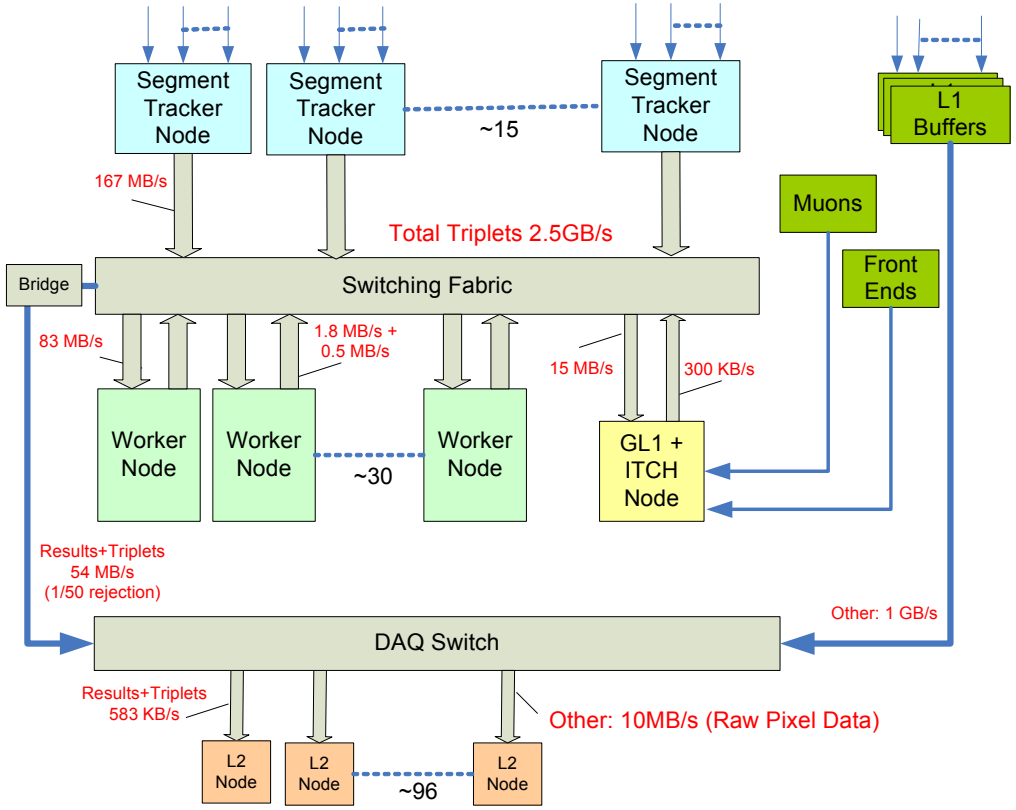
Block Diagram of Trigger & DAQ Data Flow



Online Architecture



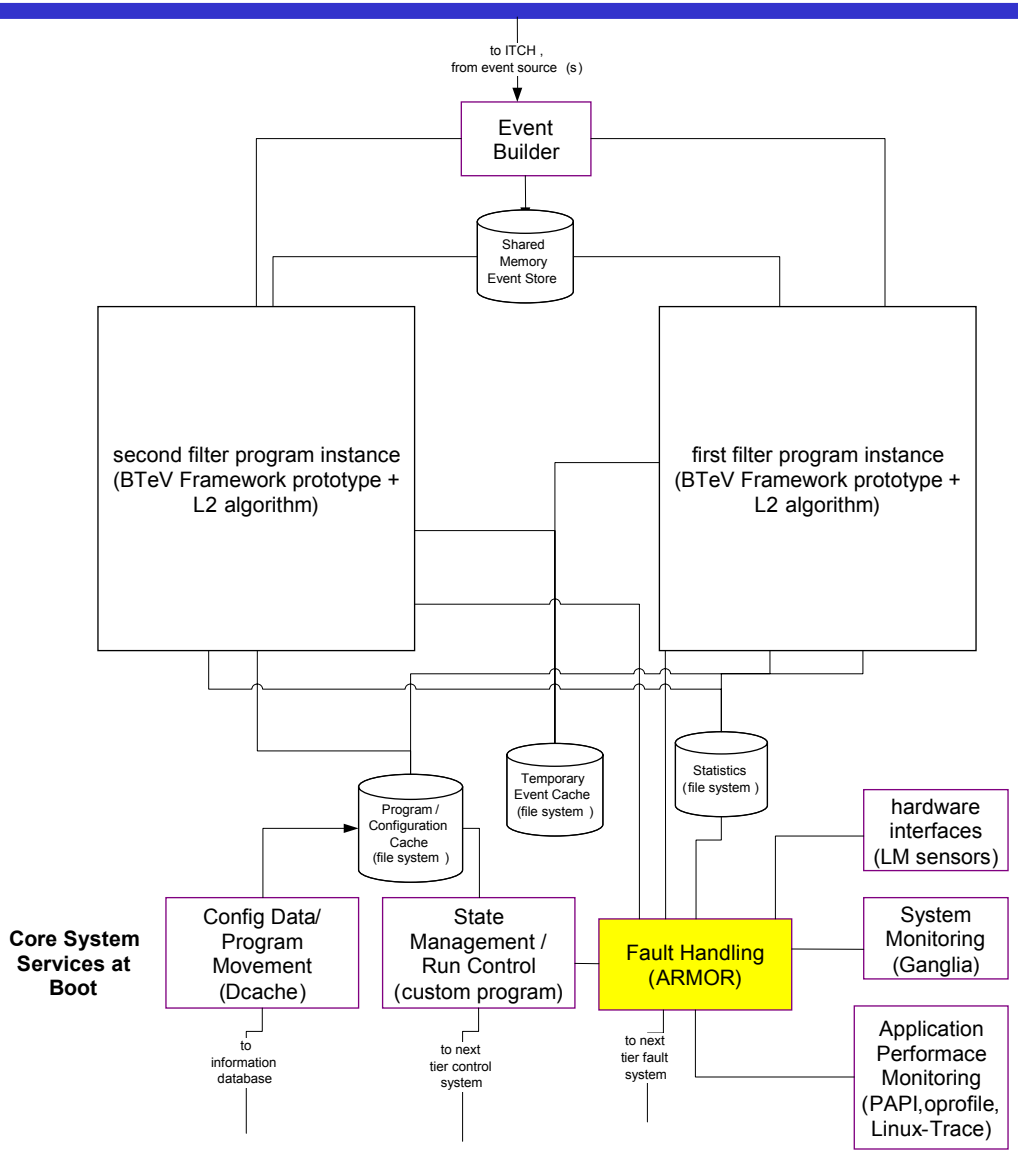
L1 Trigger


Segment Tracker Node
Segment Tracker Node
~15
Segment Tracker Node
L1 Buffers
167 MB/s
Total Triplets 2.5GB/s
Muons
Front Ends
Bridge
Switching Fabric
83 MB/s
1.8 MB/s + 0.5 MB/s
15 MB/s
300 KB/s
Worker Node
Worker Node
~30
Worker Node
GL1 + ITCH Node
Results+Triplets 54 MB/s (1/50 rejection)
Other: 1 GB/s
DAQ Switch
Results+Triplets 583 KB/s
Other: 10MB/s (Raw Pixel Data)
L2 Node
L2 Node
~96
L2 Node

RTES

- Talked about before
  - Fault tolerant adaptive embedded systems
  - Montreal talk by L. Piccoli – using Armors (one component) for process management
  - Collaboration of physicists and computer scientists
  - Near end of year 4 of 5 year grant
- Talked about again
  - Mike Haney (UofI) – BTeV and Beyond

Worker Node Software Architecture



Partitioning

- Defined as ability to run multiple data acquisition sessions in parallel.
- Commissioning goals
  - Test out subdetectors and electronics standalone
  - Test out subdetectors and electronics in gangs
  - Data collection could be a few sparse events all the way to full rate.
- Operational goals
  - Obey prime directive => collect maximum amount of physics events.
  - Corral spare cycles on the online trigger farm for offline processing in a non-disruptive way.
  - Test out new trigger algorithms
- Logical concept
  - Myriad of implementation possibilities given the 8 highway architecture and run time configurable routing tables in the DCBs

Paritioning Proposal

- Still being debated in collaboration
- Human run coordinator
  - Establish number of working highways
  - Coordinate data taking runs during this period (e.g., knowledge of who will need pixel trigger)
  - Start trigger
- Commissioning
  - Each Data taker
    - Select data sources (in units of L1 buffers) for read/write or read only (can't reset)
    - Select data syncs (in units of regional managers)
    - Select set of trigger tables
- Operations
  - Worker nodes can be manually assigned to offline partition (for long down times) in units of regional managers
  - Worker nodes can automatically shift to offline partition as luminosity decreases (can be detected by RTES)

Highlights

- Credible Design
- Standardizing inputs to DAQ/Trigger as early as possible. DCBs were single entry point, developed by a centralized institution.
- Highway architecture
  - Individual highways operating at 1/8 of full rate
  - Control overhead more manageable
  - Network bandwidth used for efficiently (larger packet sizes)
- Asynchronous L1 vertex tracker on COMMODITY hardware.
  - lower cost
  - lower risk
  - requires an increase in power & cooling
  - easier to build (less custom hardware to design)
  - requires less labor (less engineering & no DSP programming)
  - easier upgrade path (easier to add or replace processors)
- Reliable, fault adaptive system .
- Offline capabilities on online farm.

Contacts

- Contact us:
  - Btev-daq@fnal.gov
  - Btev_trigger@fnal.gov
  - votava@fnal.gov
- Talk to us
  - Mike Haney
    - The RTES Project - BTeV, and Beyond (S9-1)
  - Mike Wang
    - A Commodity Solution Based High Data Rate Asynchronous Trigger System for Hadron Collider (S14-1)
  - Jin Yuan Wu
    - The Application of Tiny Triplet Finder (TTF) in BTeV Pixel Trigger (S6-3)
    - Integrated Upstream Parasitic Event Building Architecture for BTeV Level 1 Pixel Trigger System (P8-3)
  - Luciano Piccoli
    - Unrelated talk
- Surf the web
  - http://www-btev.fnal.gov – BTeV home page include links to TDR
  - http://www-btev.fnal.gov/public/hep/detector/rtes/ - RTES home page